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Canadian Society of Civil Engineers

AN ENLARGED WATER-WAY

BETWEEN THE

GREAT LAKES AND THE ATLANTIC SEABOARD.

BY

E. L. CORTHELL,

M. CAN. SOC. C.E.

BY PERMISSION OF COUNCIL.

EXCERPT MINUTES OF THE TRANSACTIONS OF THE SOCIETY

VOL. V, SESSION 1891.

Montreal:

PRINTED FOR THE SOCIETY

BY JOHN LOVELL & SON.

1891.

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Thursday, 12th February.

J. KENNEDY, Vice-President, in the Chair.

Paper No. 48.

AN ENLARGED WATER-WAY BETWEEN THE GREAT LAKES AND THE ATLANTIC SEABOARD.

By E. L. Corthell, M. Can. Soc. C.E.

The object and scope of this paper should be clearly stated at the outset. The object is to discuss the question of the feasibility of making an enlarged water-way from the great agricultural and manufacturing centres of the West, bordering on the Great Lakes, and tributary to them, to the sea ports on the Atlantic, and to the commercial ports of the Old World.

By an enlarged water-way is meant one capable of transporting freely, and with the least possible delays, the largest freight carriers now to be found upon the Great Lakes. Any project for a commercial route that will not transport economically and with speed vessels weighing, with their cargoes, 5000 net tons, with a draught of 20 feet, will be at once eliminated from this discussion. It would be a waste of time and of public thought to propose, or even dwell upon, any project that is not fully abreast of the commercial times. Again, let it be understood at the outset, that no narrow channel, even with the draught of 20 feet, is to be considered as at all adequate for the wants of commerce, or in consonance with the principles of this discussion. Careful and thorough investigation, comparing the cost of transportation by the present methods of rail and barge and ship canals, has made it evident that nothing but unrestricted channels of the very largest dimensions for laden vessels of large tonnage will at all compare with the celerity, economy and other and numerous advantages of transportation by rail, particularly in the United States and Canada.

A glance over the history of the last half century will show that all water-way channels of an artificial nature have been far behind the demands of the rapidly increasing commerce and tonnage of vessels of

the Great Lakes. This has been appreciated by the commercial men most conversant with the conditions, but to the general public the necessity for larger channels has not always been apparent, and appeals for appropriations by Governments for such enlarged channels have been met with opposition.

Without regard to state or national lines, commercial men of Canada and of the northwest of the United States have generally been in accord on the subject of an enlarged water-way to the Atlantic seaboard. As long ago as 1863 a National Ship Canal Convention was held at Chicago, and 5000 delegates from all parts of the United States were in attendance. The special object of this Convention was to advocate the enlargement of the canals between the Valley of the Mississippi and the Atlantic.

In 1865 it was urged by an able advocate of water-way enlargement that the commerce of the Northwest had increased to so great a magnitude, that it had outgrown the Erie Canal and demanded a through route, not only to the Atlantic seaboard for its vessels, but to Liverpool; and it was asked: "Why should the lake cities with their wealth and resources not import for themselves and transact their own business? The ocean is the prerogative of no state of the Union, and the West will seek the channel which conducts its commerce with the least cost and delay."

Before the canals through New York State and Canada were even laid out, the inland seas of the continent were regarded as of so great importance, that a full and adequate ship canal from them to the ocean was looked upon as absolutely necessary. To obtain this has been the dream of commercial men during the last three-quarters of a century. That it has not been realized is due largely to the fact, that the natural water-way lies through two countries that have, as political divisions, nothing in common. There has not existed the union of action necessary to fully carry out the great projects desired by commerce. These projects have therefore never been taken up as a connected whole and pushed forward to legitimate conclusions.

It is well known that between the important ports on Lakes Michigan and Superior and Liverpool there are over four thousand miles of water navigation, and that only about 71 of them are restricted by natural obstacles in the channels. The object of this paper is to ascertain, if possible, how these natural obstacles placed here and there in the pathway of commerce may be removed, and steamships may be built on the Great Lakes to ply between their ports and the ports of the Atlantic seaboard and of the Old World.

The scope of a paper discussing so broad a subject, and one, withal, so important to the commerce and industry of great nations, must not be too circumscribed. The discussion must not be limited to certain special questions, but must canvass the entire situation, and, if possible (being given the privilege of selection), point out the best route and give convincing evidence of its superiority.

The question is not one that interests engineers alone, and there are other than engineering principles involved. We are led at once into an important commercial discussion and into the whole history of the great Northwest, particularly of the vast country tributary to the Great Lakes and the St. Lawrence River. It has to be borne in mind, also, that artificial lines of transportation—that is, constructed highways of commerce—have covered the country in every direction; that the methods of transportation upon these constructed highways have been vastly improved over those of a quarter of a century ago, and that still greater improvements will be made in the near future. We shall, therefore, be obliged to take up the subject something as follows:—

1st. Its historical features, showing the development of commerce and the increasing capacity of the channel-ways by water and by land;

2nd. The physical conditions of the present and proposed routes;

3rd. The financial and political questions involved;

4th. The commercial features of the subject.

In reference to the historical, a brief sketch will be of interest, showing the changes in the dim history of the past made in the Great Lakes, adapting themselves finally to present conditions for the benefit of man. Briefly, though not perhaps bearing directly upon our main subject, a sketch will be given of the commercial improvement southward of the Great Lakes to the Gulf of Mexico. We will then take up the present canals and channels built between the Great Lakes and the Atlantic seaboard in relation to their history; the history of the railroad system and the growth of railroad transportation will be briefly outlined. It will be necessary, also, to give a brief history of the harbour improvements upon the Great Lakes, and then in some detail the history of commerce shown by the increasing size of vessels, the increase in tonnage and the movement seaward on the Great Lakes of the productions of the Northwest. A history, also, of the gradual reduction in freight rates, both by railroads and canals on East and West routes, must be given. It will be necessary to trace briefly the growth in population, productions and commerce of the country tributary to

the Great Lakes, and particularly of the more important lake ports, such as Chicago, Duluth, Cleveland, Buffalo, Toronto and Montreal. In discussing the physical features it will be necessary to state the topographical conditions of present and proposed routes, with estimates of costs and the capacity of these routes when completed, and give a comparison of the length of routes now existing and projected. The author having found it necessary to discuss the feasibility and desirability of constructing at certain points on the routes ship railways, a general sketch and brief argument in favour of the practicability of such a method will need to be given, and a comparison made between this method and that by ordinary canals and railroads.

The financial and political subject will embrace the question of what it will cost each of the two Governments to carry out the plans proposed, or the cost to private companies of constructing the proposed routes; and under this subject the relations of the two Governments to each other, so far as relates to commerce, must be briefly stated.

In discussing the commercial features it will be necessary to predict the effects upon the various large ports of the Great Lakes and the St. Lawrence, and, also, of the Atlantic seaboard, of completing and putting into operation the water-way, or the water-ways, recommended; and to state also the probable changes in methods of transportation which will take place, and also the change in the methods of trade with the Atlantic seaboard and with Europe, when steamers of 5000 tons displacement weight, when laden, are built on the Great Lakes, and put in direct trade between lake ports and the ports of the Atlantic seaboard, Great Britain and the Continent.

Great and astonishing changes have taken place in comparatively recent geological times in the basins of the Great Lakes. There are well defined high water marks to indicate, at least, that the three great Northwestern lakes were probably 200 feet higher than they are today; that there was a still greater lake, now Lake Winnipeg; that the immense overflow from all these lakes flowed southward to the Gulf of Mexico; and that great areas of country now inhabited and cultivated by man were at that time submerged to a great depth.

The great valleys of the Illinois River, the Minnesota River, and the Upper Mississippi as well, now occupied by comparatively small streams, prove conclusively that at a comparatively recent period there flowed southward great volumes of water, and that Lake Winnipeg drained southward, although now draining northward. A hypothesis was advanced, and an endeavour made to sustain it, by the late General Warren, to account for this remarkable change in the drainage of the

continent. He attributed it to a great cyclic change in the continental slopes which depressed the northerly part of the continent and raised the southerly, as, for instance, the Florida Peninsula, as well as Cape Cod and other formerly submerged portions of the Atlantic Coast. This great southerly current of the vast interior basins of fresh water of the continent was hemmed in on the south by an ancient barrier, which evidently crossed the Mississippi near Grand Tower, Ill.; but the waters gradually cut their way through, and thus largely drained the great inland sea. Either by this means or by the changes in the continental slopes, the waters were drained from the land, and the conditions were slowly changed until we have the Great Lakes of to-day.

At Chicago is the lowest line in the cross-section of the trough or "thalweg" through which the waters of the lakes flowed southward. The bottom of this trough is only about 8 ft. above the present level of Lake Michigan, with a natural drainage and a steep slope down the Illinois River Valley from the immediate suburbs of the city. At this location has been built within the last half century the second city of the continent, and at this point, connecting the lake with the tributaries of the Mississippi River, there was projected in 1670 a canal to the Illinois River. It was proposed by one of the earliest pioneers—Joliet—to dig a canal across the Chicago Divide for commercial and military purposes. In 1804 Albert Gallatin, secretary of the Treasury of the United States, spoke of the national character of this proposed waterway. In the first comprehensive report on internal communication, DeWitt Clinton and Gouverneur Morris in 1808 to 1825 urged the "proposed ship canal" as an extension of the Erie Canal to the Mississippi, in order to open up water communication by the lakes from the Hudson River to the Gulf of Mexico. The Congress of the United States assisted in the project, and made a land grant of 284,000 acres in 1827 for the construction of the work. The first canal was opened for navigation in 1848. In 1865 the State of Illinois provided for its completion; it was completed by the city of Chicago for drainage purposes in July, 1871, but the flow through it proved insufficient for the purpose, and in 1881 the State required the city to erect pumping machinery of a capacity of not less than 60,000 cubic feet per minute, which was put into operation in 1884. The original canal was six feet deep, sixty feet wide at surface, thirty-six feet wide at bottom in earth, and forty-six wide in rock, with locks, one hundred and ten feet long, eighteen feet lift and six feet on the miter sills.

The rapid growth of the city requires a much more adequate drain-

age for its sewage than is now provided. This is necessary to prevent the pollution of the only source of its water supply, and to carry the sewage away from the city as quickly as possible. A channel for drainage purposes as well as for navigation purposes has been authorized by the State Legislature. Nearly the entire area of the city has, under the State law, been organized into a drainage district. The law requires (and this requirement it may be stated was demanded by the towns and cities located along the Illinois River) a continuous flow of not less than 300,000 cubic feet per minute, with a current not exceeding three miles an hour and 600,000 cubic feet per minute, when the population of the district draining into the channel exceeds 1,500,000, with a requirement for a still larger volume when the population exceeds the number last named. It is specified that the water shall not be less than eighteen feet deep through the channel, and that the width of the channel shall not be less than one hundred and sixty feet at the bottom. By a joint resolution the Legislature requests the United States Government "to aid in the construction of a channel not less than 160 feet wide and 22 feet deep, with such a grade as to give a velocity of 3 miles per hour from Lake Michigan at Chicago to Lake Joliet, a pool of the Des Plaines River immediately below Joliet, and to project a channel of similar capacity and not less than 14 feet deep from Joliet to La Salle, all to be designed in such manner as to permit future development to a greater capacity." It is apparent from the rapid growth of the city, that long before these works, so great in magnitude, and costing probably twenty-five or thirty millions of dollars shall have been completed, there will be at least 2,000,000 of people in the drainage district. The normal growth of the city will, no doubt, make the population as great as this before the year 1900. The large quantity of water to be sent through this channel into the Illinois River Valley will, it is expected, raise the low water level of the Illinois River about 7 feet, and that of the Mississippi River at St. Louis at least one foot, and probably six inches at Cairo at the junction with the Ohio River. On the Mississippi River itself the United States Government is expending large sums of money in deepening and rectifying the channel for navigation, with the ultimate purpose of obtaining a minimum depth of 10 feet at low water between New Orleans and Cairo, a distance of about 1000 miles by the course of the river. As is well known, it has expended a large amount of money in removing the obstructions at the mouth of the Mississippi, and has created by the works there a channel 30 feet deep between the river and the Gulf of Mexico. This result was obtained in 1879, and the channel has

increased rather than diminished in size since that day through the jettied channel. As incidentally of interest, it may be stated that the United States Government is about to connect the navigable waters of the Illinois River with those of the Mississippi River by a canal across the country from Hennepin on the Illinois River to Rock Island on the Mississippi River. This is not to be a ship canal but a boat and barge canal. The depth on the miter sills of the locks is to be 7 feet, the width at surface of the water 80 feet, and the locks are to be 170 feet by 30 feet. There will be 37 of these locks. The height to be surmounted from Hennepin going westward to the summit in a distance of 20 miles is 208 feet. The difference in level between this summit and the Mississippi River at Rock Island is 102 feet, the length of the canal will be 77 miles. The entire distance between Chicago on Lake Michigan and Rock Island on the Mississippi River, by way of the Illinois River and the Illinois and Mississippi canal, will be 193½ miles. The plans are made for the work, and construction is expected to begin soon.

One question in relation to the proposed drainage and water-way channel between Chicago and the Mississippi River is, what effect, if any, will the abstraction of so large a volume of water from Lake Michigan have upon the level of that lake and of Lake Huron and upon the volume flowing through the Detroit River into Lake Erie? This is an international question, and should be briefly considered in connection with the general subject which we are discussing.

On September 8, 1888, a paper by Mr. George Y. Wisner, civil engineer, was read before the Western Society of Engineers, entitled: "Levels of the Lakes as affected by the proposed Lake Michigan and Mississippi Water-way." Mr. Wisner had had at that time about 20 years' experience on the rivers, harbours and lakes of the Northwest, and was connected with the Great Lakes surveys. The facts which he gave and his discussion of the subject were reviewed by several hydraulic engineers of the country. This discussion in printed form accompanies the present paper for the purpose of information. It is not intended here to do more than to state the general opinion on the subject as given by those who took part in the discussion. The opinion as stated by Mr. Wisner was that "probably the low water level of the lake would never be affected to exceed 2½ in. by withdrawing 10,000 cubic feet per second from Lake Michigan for the proposed water-way. The lowest stage occurs in Winter when navigation is closed." "The annual rise of the lake usually covers a period of about four months, and consequently the variation in the yearly fluctuation of the

lake surface, due to withdrawing such a volume of water, could not exceed one inch." "When we consider that hourly fluctuations of the lake surface of from 6 to 30 inches in amplitude are constantly taking place, it is evident that the withdrawal annually of a volume of water from Lake Michigan, equivalent to 3 inches in depth over the surfaces of the two lakes, would not be appreciable in any ordinary set of gauge readings, and would certainly have but little effect upon the depth of water in the connecting water-ways." Somewhat similar artificial conditions have been produced by the deepening of the St. Lawrence rapids below Ogdensburg from 10 to 16 feet, adding from 6 to 8 per cent. to the free channel of the river. The question was considered at that time, and was referred to the United States Engineer Department, and the conclusion from the investigation was, that the effects would extend to no great distance, and that the level of Lake Ontario would not be impaired. The deepening at the Lime Kiln Crossing of the Detroit River where the depth has been increased from 13 to 20 feet, and at the St. Clair Flats which have been deepened from 9½ to nearly 20 feet, are cases generally similar to what is practically the deepening of the channel now existing between Lake Michigan and the Illinois River, and yet no injurious results have been experienced or are they anticipated. We may, therefore, dismiss any fears that may exist in regard to the deleterious effects of this channel-way upon the harbours and the connecting water-ways of the lakes.

Taking up again, after this diversion, the general features of our subject, with the intention of following it through in its logical order, we should look upon the Great Lakes, so called, or really inland seas of fresh water of immense magnitude, as simply the enlargement of the St. Lawrence River into which they pour their surplus waters. This chain of lakes, or the river, has its source in Eastern Minnesota at the head of St. Louis River, and almost coincident with the source of the Mississippi and the Red River of the North. The river ends at Cape Gaspé at the head of the Gulf of St. Lawrence.

We are contemplating the most magnificent inland navigation in the world. The basin of its drainage is 457,000 square miles. Lake Superior, the largest body of fresh water on the globe, has an area of 31,200 sq. miles. It is 412 miles in length and 167 miles in breadth, with a maximum depth of about 1000 feet. Its surface is 602 feet above mean high tide of the ocean. The outlet of this lake is the St. Mary's River, 55 miles in length. The difference of elevation between Lake Superior and Lake Huron is 22 feet, of which 18 feet is in the St. Mary's Rapids which are one half mile in length. Lake Huron is 265

miles long, 101 miles broad, with a maximum depth of 702 feet, and is 581 feet above sea level. The area of this lake varies, by different authorities, from 15,760 square miles to 23,800, depending upon what areas of adjacent bays are included. Lake Michigan, connecting with Lake Huron by the Straits of Mackinaw, is 345 miles long, 84 miles wide, and 581 feet above sea level. Its area is 22,450 sq. miles. Lake Huron discharges southward through the St. Clair River, 33 miles in length, Lake St. Clair 21 miles, and the Detroit River 18 miles in length, and then into Lake Erie which is 250 miles long by 60 miles wide, with an area of 9960 sq. miles. Its maximum depth is 201 feet. It is 573 feet above tide and is 326 feet above Lake Ontario, which is the next enlargement eastward of the St. Lawrence chain. The Niagara River between these two latter lakes is 33 miles in length; Lake Ontario, the most eastern of the lakes, is 190 miles long, 54 miles in width, and has a maximum depth of 738 feet, and is 247 feet above the sea. Its area is 7240 sq. miles. From the city of Kingston at the eastern end of Lake Ontario to the ocean the distance is 1164 miles, though Cape Gaspé, which is considered the mouth of the St. Lawrence River, is 400 miles from the ocean.

The St. Lawrence between Ogdensburg and Montreal is obstructed by rapids at several places, which have been improved either by removing the obstructions in the natural channels or by flanking them with artificial canals. From Montreal to the Gulf of St. Lawrence a navigable depth for ocean vessels exists by nature, except at a few points where the channel has been improved by dredging to over 27 feet and to ample width. The improvement in the St. Lawrence River from Lake Ontario to the Gulf of St. Lawrence has been made by and at the expense of the Canadian Government.

The historical features will embrace a sketch of each of the following constructed works: the St. Mary's Falls Canal, between Lake Superior and Lake Huron; the St. Clair River and Lime Kiln Flats improvements between Lake Huron and Lake Erie; the Welland Canal, joining Lake Erie and Lake Ontario; the Trent River navigation, between Lake Huron and Lake Ontario; the St. Lawrence River improvements; the Erie and Oswego Canals, in New York State; the Lake Champlain and Hudson River Route in New York.

In the "physical features" will be included a brief history of the following projects: the Ottawa Ship Canal between Georgian Bay and Montreal, the Georgian Bay and Toronto Ship Canal, and its successor the Hurontario Ship Railway, the Niagara Falls Ship Canal and Ship Railway on the United States side of the river, the Michigan Pen-

insula Ship Canal and Ship Railway, and the projected Ship Canal via Lake Champlain.

A sketch of the railroad history will be briefly given.

The Map Plate II shows the present and proposed routes.

ST. MARY'S FALLS CANAL.
(Commonly called the Sault Ste. Marie.)

As early as 1837, the project of building a ship canal around the Falls of St. Mary's River was discussed in the Legislature of the State of Michigan. The matter was brought before Congress in 1840, but was opposed, one of its opponents—the distinguished Henry Clay—speaking of it as "a work beyond the remotest settlement in the United States, if not in the moon." This was only half a century ago.

The first step taken by the General Government of the U. S. towards the improvement of this water-way was in 1852, 750,000 acres of public land being donated to the State of Michigan, to enable it to construct the canal, and a right of way 400 feet wide granted through the Military Reservation at the Falls of St. Mary's River, on which to build the work. The conditions were that the canal should be at least 100 feet wide with a depth of 12 feet, with locks 250 feet long and 60 feet wide. The canal was opened to commerce in 1855; the locks (two in number) were 220 feet long and 70 feet wide. In 1882 nearly $2,500,000 had been expended on the canal and its approaches. The prism of the canal had been changed from a uniform width of 100 feet to a width varying from 500 feet at the upper entrance to 108 feet at the narrowest part and 270 feet immediately below the locks, and the depth from 12 feet to 16 feet at a mean stage. A new lock had been constructed 515 feet long and 80 feet wide with 17 feet of water on the miter sills. These dimensions, however, proving inadequate for the rapidly increasing size and draught of vessels, Congress in 1886 provided for a still larger lock, based upon a navigation of 20 feet depth through the canal and its approaching channels. The new lock is to be 800 feet long between the gates and 100 feet wide, with 21 feet depth of water on the miter sills. The estimate for an enlargement of the canal and the construction of this lock is $4,738,865. The lock overcomes a height of 18 feet. This lock is now under construction.

ST. CLAIR RIVER IMPROVEMENTS.

The next obstruction to be overcome is between Lake Huron and

Lake St. Clair. A canal through what is called the St. Clair Flats was projected in 1866 for the purpose of obtaining a straight channel (in place of the tortuous natural channel), 13 feet deep, 300 feet wide and about $1\frac{1}{2}$ miles in length, each side being protected by timber dikes resting on piles; the cribs thus formed being filled with material dredged from the channel and backed by dredged material. In 1873 the channel was deepened to 16 feet by dredging a width of 100 feet on each side of the channel axis. Here also it was found necessary to deepen and enlarge the channel for the enlarging commerce. The project now contemplates a double row of sheet piling to a depth of 26 feet along the channel face of each of the old dikes, dredging the area between the dikes to a depth of 20 feet, and continuing the channel above and below the canal to the same depth in the river and in the lake. On this work there has been expended nearly $700,000.

The Lime Kiln Crossing at the mouth of the Detroit River is also being deepened to 20 feet. The depths demanded by and obtained for the increasing commerce through these channels have been as follows:—

1858	$9\frac{1}{4}$ ft.	1871	12 ft.
1874	13 "	1885	16 "
1890	20 "		

WELLAND CANAL.

The history of this important artificial water-way connecting Lakes Erie and Ontario, by flanking Niagara Falls and surmounting a height of about 326 feet, is too varied in its nature and has too many details to burden this paper with more than a brief summary. It is nearly three-quarters of a century since the building of this canal was taken under serious consideration. The first project was to build a canal and railroad combined, that was in 1824, but the railroad feature was dropped, and the work began with wooden locks 110 feet long, 22 feet wide, with 8 feet of water on the miter sills. Water was let into the canal in 1829, and two vessels were taken from Lake Ontario to Port Robinson on the Welland River in that year. The financial embarrassments of the Company, however, compelled it to obtain a grant from the Canadian Government, one of the requirements of which was the extension southward to Lake Erie on nearly the same line as now exists. The canal was open to the passage of vessels in 1833. The channel was narrow as well as the locks. In 1841 the Government appropriated some money towards the enlargement and improvement

of the canal and to make the structures permanent. According to the decision of 1843, the locks were to be made 150 feet long by 26½ feet wide, with 9 feet on the sills, with 11½ feet of water on the sills in the entrance locks. The estimated width of the straight parts of all the reaches was to be not less than 26 feet. This enlargement fully doubled in capacity both the prism and locks of the original design. In 1880 another enlargement more than trebled the size of 1843, the width being 100 feet at the bottom. The tonnage of vessels that could pass through the canal at that time was fully six times greater than that which could pass through the original canal in 1841. There were at that time (1880) 27 locks, each 270 feet by 45 feet. But these dimensions proved entirely inadequate to the size of vessels, and another enlargement took place, the locks of which are 270 feet by 45 feet with 14 of water on the miter sills. These are the dimensions of to-day. The length of the canal is now 26¾ miles. There are three guard gates and 25 lift-locks. The total rise, or lockage, is 326¾ feet. It may be interesting to know that there has been expended on this canal up to the present time, or to 1889, $23,787,950.30 according to the official reports.

TRENT RIVER NAVIGATION.

This canal, or series of canals, and open navigation of rivers and lakes, is mentioned simply for the reason that at times in the past it has been suggested as a possible route for a large ship canal. This navigation is a series of disconnected water stretches, extending from Trenton at the mouth of the Trent River at the Bay of Quinté, Lake Ontario, to Lake Huron, but this route has never been used for anything except local traffic, as it has a depth of but 5 or 6 feet. The entire length of the route is about 201 miles. The beginning of the work dates back to 1837. The total lockage of the Trent Valley route is 1044 feet. The impracticability of transferring this circuitous route over an undulating country into a ship canal of adequate dimensions to carry the traffic of the Great Lakes to the seaboard is apparent without any argument.

THE ST. LAWRENCE IMPROVEMENTS.

These improvements have consisted partly in dredging and removing obstructions from the natural channel, but mostly in the construction of canals to flank the very troublesome and dangerous rapids

which exist at places between Kingston and Montreal. The canals are the Lachine near Montreal, Beauharnois, Cornwall, Farran's Point, Rapide Plat and Galops, their combined length being 43¼ miles—Lachine 8½, Beauharnois 11¼, Cornwall 11½, Farran's Point ¾, Rapide Plat 4, and Galops 7⅝ miles. In 1841, when the system of canals between Montreal and Lake Ontario was designed, it was intended to obtain a depth of 9 feet, but on account of fluctuations in the river itself the depth in the canal could not always be maintained. At times it fell in some of the canals to 6 ft. 7 inches.

In 1871 it was decided to enlarge the canals on the St. Lawrence, to afford a navigable depth of 12 feet throughout, and then again shortly afterwards it was decided that the ultimate depth should be sufficient to accommodate vessels of 14 feet draught. Work has been carried on since that time with this object in view, the locks are to be 270 feet long between the gates, 45 feet wide, and with a clear depth of 14 feet on the sills. This work has not been entirely completed, but for the purposes of this paper and the estimates which will follow for a still larger water-way, the work is assumed to be entirely performed. In round numbers it may be stated that the entire amount expended on the St. Lawrence system from Lake Erie to Montreal is about 41¼ million dollars, and it may be estimated that it will require to obtain a depth everywhere in the river and in the canals of 14 feet 12¾ millions more, or about $54,000,000 in all, not including the cost of the construction of the canal at the Sault Ste. Marie and other necessary improvements. Therefore, to obtain, between Lake Superior and Montreal, a full depth of 14 feet, it will cost, all told, about $60,000,000.

ERIE AND OSWEGO CANALS.

While it is not probable, and perhaps not possible, that the Erie Canal can ever be made to perform a greater part, or as great a part, in the development of the country than it has already performed, yet on account of its past usefulness it is necessary to briefly sketch its history.

It extends from Buffalo on Lake Erie to Albany on the Hudson River, a distance of 350.5 miles, with 71 locks 7 feet deep, 110 feet long and 18 feet wide. The total lockage is 657 feet. This was in 1865, and the total cost of the canal up to that time had been $38,-977,830.

The Oswego branch of the Erie Canal leaving Lake Ontario at

Oswego is 38 miles in length, and it descends 155 feet from the Erie Canal to Lake Ontario with 18 locks 110 feet long by 18 feet wide. The total cost in 1865 had been $3,077,429. Improvements and enlargements have been made from time to time.

The entire expenditure on the Erie Canal up to 1886 had been $133,000,000.

LAKE CHAMPLAIN AND HUDSON RIVER.

The present route of this canal is from Sorel on the St. Lawrence River, 46 miles below Montreal, up the Richelieu River through the St. Ours Lake to the Basin of Chambly, thence up the Chambly Canal to St. Johns and the River Richelieu to Lake Champlain, the distance in Canada being 81 miles, thence up Lake Champlain. At Whitehall, the southern end of Lake Champlain, the Champlain Canal is entered, and connection is obtained with the Hudson River. The total distance to Albany, 7 miles of which is by the Erie Canal, is 265 miles. The total lockage from the St. Lawrence River to the summit level of the Champlain Canal is 136¼ feet upwards, and the total lockage down to Albany 150 feet. The total distance to New York by this route is 411 miles. The canal is generally of very moderate proportions, being about 36 feet wide at the bottom with 7 feet of water on the sills.

RAILROADS.

One of the most important factors in transportation during the last half century has been the railroad. Its growth, especially in the United States, has been almost marvelous. Its effect upon the cost of transportation has been to continually reduce it, principally by competition with waterways and among the various lines of railroads. The methods have become so nearly perfect, and the cost of transporting goods so greatly reduced, that the ordinary barge canal, which before the advent of the railroad played so important a part in the development of the country, will not in any sense compete with it. Over one half of the entire mileage of canals of half a century ago has been abandoned, many of the old canal beds have been used for railroad tracks,—those that do exist are for special purposes, and most of them survive by the generosity of the States, which have removed all tolls from them and have maintained them at the public expense. It is not intended by this statement to depreciate the immense value which these former means of transportation have been to the country,

but to state that a better method has come, and that the only possible means of competing with this better method is to make one better still.

Since 1840 the growth of the railroad system tributary to and bordering upon the Great Lakes has been as follows: In 1840 there were in this tributary country in the United States 89 miles of railroad; in 1850, 1276 miles; in 1860, 10,238 miles; in 1870, 19,703 miles; in 1880, 37,456 miles; in 1889, 63,688. In 1889 these railroads moved 208,179,478 tons of freight. In Canada there were in 1889, in its two principal railroad systems, 8087 miles, making a total more or less tributary or adjacent to the Great Lakes and the St. Lawrence River of 70,775 miles. These railroads have in connection with the transportation facilities of the lakes built up great centres of population and trade. These cities lie directly upon what may be made a continuous and adequate water-way to the seaboard. The immense commercial business which is transacted annually at one of these great commercial ports may be appreciated by an examination of the following statement of the traffic at the city of Chicago in 1889:—

Length of main lines of railroad terminating at Chicago.............................	54,411 miles.
Number of freight cars received and forwarded.	4,248,769
Tons of freight received and forwarded.	43,013,444

While the railroads with their important facilities carried a larger part of the products westward, the record of 1889 shows that there were transported on the lake two-thirds of all the cereals that went eastward.

HARBOURS.

The United States Government has not only deepened the channels between the lakes, and vastly improved them for a large traffic and for the increasing size of vessels, but it has inaugurated a system of harbour improvement of equal capacity. Its present policy is to improve the harbours of the principal ports, so that there will be a depth of 20 feet, the depth of the entrance channels to be the same. In harbours of minor importance the depth of the entrance to depend upon the improvements of the harbour and the facility with which it may be improved. The average depth at present in the harbours of the large and important ports is 16 feet.

COMMERCE.

1st. Increase in the size of vessels.

In 1859, 36 of the largest propellers on the Great Lakes averaged about 700 tons net register. The largest was 981 tons and the smallest of this number 583. The draft when fully loaded was about 11 feet, greatest draft 11½ ft. Without tracing the growth of intermediate steps, it may be stated that in 1890, what is called the business fleet of the Great Lakes consisted of 2055 vessels of 826,360 net register tons. Its value is $58,125,500. Of these 1153 are steam vessels, 232 of these steamers are over 1000 tons register, 110 are over 1500 tons, and half of the larger class range from 1600 to over 2100 tons net register, and carry a cargo of from 2850 net tons to over 3700. The draft of these vessels is at present limited by the depths of the channels and harbours, being a maximum of about 16½ feet, but many of them could safely and profitably load to 19 or 20 feet.

The Inland Lloyd Register of 1886 shows a total valuation of Lake vessels of $30,597,450 against $58,128,500 in 1890. The type of vessels also has greatly changed. In 1886 there were only 21 steamers of over 1500 net register tons. In 1890 there were 110 such steamers. In 1886 there were six steel vessels on the lakes valued at $694,000. In 1890 there are 68 valued at $11,964,500. The Census of 1890 shows that there was carried on the Great Lakes in 1889 27,417,598 net tons of cargo. The increase of commerce upon the Great Lakes may be appreciated from the increase in and out of Lake Superior. In 1870 the entire amount passing through the St. Mary's Falls Canal was 690,826 net registered tons; in 1880, 1,734,800 tons; in 1883, 2,042,259; in 1887, 4,897,598; in 1889, 7,221,935; in 1890, 8,454,435; and the actual weight of cargo carried in 1890 was 9,041,213 net tons. The value of this tonnage has increased as follows: in 1881 it was $28,965,612.94; in 1885, $53,413,472.13; in 1889, $82,732,527.15; in 1890, $102,214,948.70.

An excellent summary and comparison of lake commerce made by London *Engineering* of date September 26th, 1890, is here given for the purpose of showing forcibly and reliably the vast importance of the commerce of the great lakes:—

"A recent article in Bradstreet's gives some surprising statistics of the commerce of the Great Lakes. During 234 days of navigation last year, tonnage passed through the Detroit River to the amount of 10,000,000 tons more than the entries and clearances of all the seaports in the United States, and 3,000,000 tons more than the combined

foreign and coastwise shipping of Liverpool and London. This does not include traffic between Lakes Superior and Michigan or Lakes Erie and Ontario, or local traffic between ports on these lakes. Nearly three times as many boats yearly pass through the St. Mary's Falls Canal at Sault Ste. Marie as through the Suez Canal, with an aggregate tonnage of 7,221,935 in 1889, against 6,783,187 for the Suez Canal, though with only 234 days of navigation, whereas the Suez Canal is open all the year round. The figures for the lake shipbuilding are equally striking. Last year the tonnage constructed by lake builders was almost exactly equal to that of the Atlantic, Gulf and Pacific shipyards combined. The lake vessels numbered only 225 out of a total of 994 for the country (exclusive of western river boats), but this fact shows that on the average the lake builders launched a better class of vessels. On the lakes were built only four less steamers than on the Atlantic and Gulf coasts, and their tonnage was more than twice as great. Of the whole steam tonnage of the United States, about a third is on the lakes, and of steamers between 1000 and 2,500 tons they have more than half the total. Naturally the sailing tonnage is not great, but it is half as large again as that of the Pacific slope. Last year there were twenty-one sailing vessels of more than 1000 tons on the lakes and 156 between 500 and 1000 tons. The growth of ship-building on the lakes has been very marked in the last few years. In 1886 87 there were thirty-one boats built valued at $4,074,000; in 1889-90 there were fifty-six built, valued at $7,866,000. The tendency, as elsewhere, has been toward iron and steel for large ships. Ten were built of steel in Cleveland in 1888-89, aggregating 22,989 gross tons. One of steel and one of iron were built in Detroit and two of iron in Buffalo."

The immensity of the long distance lake traffic will be appreciated from the following statement:—

The traffic through the Detroit River in 1888 was about 19,000,000 net register tons, the number of vessels 31,404, exclusive of traffic between foreign parts; in 1889 it was about 22,000,000 tons; in 1890 over 23,000,000 tons. The tonnage in and out of Duluth increased in the four years previous to 1889 from 1,372,233 tons to 2,452,113 tons. At Buffalo the tonnage of lake vessels was about 6,006,000 in 1888, and nearly 7,000,000 in 1889.

The total lake arrivals and clearances at the port of Chicago in 1889 was 10,268,031 tons, in 1870 it was 6,033,207 tons, an increase of 72 per cent. in 20 years.

While this unprecedented increase of commerce upon the Great Lakes

has been going on during the last few years, and is evidently destined to increase to still greater proportions, and while the railroads of the country are transporting much of this freight from what are practically the Eastern termini of the lake commerce at Buffalo, Cleveland and Erie to New York, Philadelphia and Boston, the water-ways out of the eastern end of Lake Erie and beyond to the sea have had no appreciable increase; in fact, there has been a decrease during the last 15 years. The Erie Canal is carrying no more than it did many years ago, and through the Welland and St. Lawrence River Canals there has been practically no increase. In 1883 the total tonnage on the Welland Canal was 880,957, in 1887, 787,307; on the St. Lawrence Canals in 1883, 1,847,865 tons, and in 1887 1,715,295 tons.

There is no question that one of the principal reasons for the commerce through the canals east of Lake Erie remaining practically stationary, or decreasing, is the fact that they are not adequate for the business.

The Welland Canal has 14 feet depth of water. According to the United States Bureau of Navigation Report of 1889, there were 330 United States vessels in the Great Lakes above Niagara Falls which drew too much water when loaded to go through this canal, of which 86 were sailing vessels with a registered tonnage of 74,500, and 244 steam vessels with a tonnage of 369,692, or a total tonnage of 444,192, that could not pass through the Welland Canal. Those that passed through in the season of 1889, most of which were United States vessels, were obliged to reduce their cargoes from a total tonnage of 71,502 to 63,283 tons in order to pass through.

Improved methods of transportation by rail and increase in the size of lake vessels, the rapid increase in the cargoes and tonnage of the vessels, the rapid growth of steam transportation, and the rival competition which exists between the various lines and between the railroads have compelled a continual reduction in the cost of transportation to the public. From careful records kept by the United States Government Engineer in charge of the St. Mary's Falls Canal, it was ascertained that the cost per ton per mile of carrying freight an average distance of about 800 miles was, in 1887, 2.3 mills and in 1889 1.5 mills. Rates on other lake lines favourably compare with this. It is estimated by Mr. Charles H. Keep, secretary of the Lake Carriers Association, in a paper addressed to the United States Congress, December 5th, 1890, that the value of the entire cargoes carried on the lakes this last season was $305,432,041.72. He estimated that the average distance of carriage of the entire commerce of the Great Lakes is 566

miles, which would make the total ton mileage for 1889 15,518,360,-468. The entire mile tons of railroad carriage in the United States in the year ending June 30th, 1889, was 68,727,223,146; in other words, the freight service on the Great Lakes is 22.6 per cent. of the total freight service rendered by all of the railroads of the United States. At the average railroad rate of all the freight moved in 1889, according to the statistician of the Inter-State Commerce Commission, 9.22 mills per ton per mile, the cargoes carried on the lakes in that year would have cost the shippers \$143,079,283.51. Adopting $1\frac{1}{2}$ mills per ton per mile as the average cost of lake transportation the entire cost for the season of 1890 was \$23,177,540.70. The saving to the public therefore by water transportation on the lakes in that single year was \$119,801,742.81. Much of the heavy freight has been carried for considerably less than $1\frac{1}{2}$ mills per ton per mile. Anthracite coal is carried from Buffalo to Duluth and Superior, a distance of 1000 miles, for 30 cents per ton, or $\frac{3}{10}$ mill per ton mile.

The total tonnage of freight moved in the Central Northern and Northwestern groups of States, according to Poor's Manual, was, in 1888, 195,773,526. The increase of foreign trade at the Atlantic ports was, between 1870-89, from 9,155,659 to 15,952,119 tons.

A detailed history of the reduction in rates between the Northwest and the Atlantic seaboard by river, canal and rail would be of great interest in this discussion. We cannot, however, give more than some of its salient points.

During 1852 (the first year of free competition between canals and railroads) the New York Central Railway hauled flour from Buffalo to Albany for 60 cents per barrel, which is nearly 50 cents below the average price transported by canal for nearly 20 years subsequent to the opening of the canal. The above is equivalent to about \$6.00 per ton, or a little over 2 cents per ton mile. On the railways of the State of New York in 1855 the average receipts per ton mile for freight were 2.79 cents. About this time a report signed by the superintendents of the four Trunk Lines claimed that the lowest rates at which ordinary freight could be carried and pay interest and expenses was an average of 2 cents per ton mile for heavy agricultural products, 3 cents for groceries, and 4 cents for dry goods. In 1858 the Lake Shore & Michigan Southern Railway forwarded from Chicago to New York 43,304 tons of freight at an average rate of 2.38 cents per ton mile.

The average charge per ton of wheat from Chicago to New York during 1868 to 1872 was as follows: All-water route 5.54 mills per ton mile. The average of the four years, 1868 to 1872, lake and rail

route, 6.66 mills; all rail 12.79 mills. The rate per ton mile by the present shortest rail route is about 5 mills. During 1878 the wheat rate by water from Chicago to New York was something under $3.30 per ton, or 2.3 mills per ton mile.

During the season of 1879 grain was shipped from Chicago to Liverpool for 17 cents per bushel, a rate but little greater than was paid for transportation by canal from Buffalo to New York, only ten years before, that is, in 1869. In 1890 grain was shipped from Chicago to Liverpool for $9\frac{3}{4}$ cents per bushel.

The average lake rates from Chicago to Buffalo on wheat have been as follows:—

1861	11	cents per bushel.
1865	9.7	" " "
1870	6.2	" " "
1875	3.5	" " "
1878	3.1	" " "
1889–90	2.5	" " "

Large steamers with barges in tow can transport grain at 2 cents a bushel between Chicago and Buffalo with a profit.

The growth in population of some of the lake cities will give an idea of the growth of the commerce of the country tributary to the Great Lakes.

Population of Buffalo in 1850 was	42,261
" " " 1890	255,000
Cleveland in 1860	17,034
" 1890	262,000
Chicago in 1850	29,963
" 1890	1,100,000

The above general commercial statement has been compiled from a large amount of detailed information, which has been placed in the author's hands by the kindness of the officials of the United States and Canadian Governments, and by the officers of Transportation Lines and Secretaries of Boards of Trade of the lake cities, and obtained from other reliable sources. This one subject of the growth of the commerce of the Great Lakes, the reduction in freights, and the actual cost of the same, and a description of the methods of transportation both by rail and water, would of itself form a most interesting and important paper.

It is necessary now with these general facts in mind to take up the physical features of the present and projected routes, and ascertain if

it is practicable to develop, within a reasonable cost, a commercial route between the Great Lakes and the Atlantic seaboard.

PHYSICAL FEATURES.

The brief historical summary of the constructed or partially constructed water-ways, with almost constant improvements and enlargements, by both the United States and Canadian Governments, to keep pace with the rapidly increasing commerce of the Great Lakes and the increase in dimensions of vessels, and particularly in their draught, leads us, in our discussion, to attempt to predict for the near future, either by lake, river, canal or by other adequate means, an enlarged commercial highway between the Great Lakes and the seaboard. Any one who traces the very interesting history of the improvement of the water-ways up to this time, and studies only casually the history of commerce on the Great Lakes, will be led quickly and inevitably to a conclusion that the opinion outlined in the beginning of this paper is correct, that a channel large enough for vessels of a draught of 20 feet, the cargoes of which will average not less than 3000 tons weight, is absolutely necessary. The various projects, with their estimates following, are based on these requirements.

The "Soo" Canal and lock, now being built by the United States Government, is fully equal to these requirements. The canal being built by the Canadian Government is not equal to them. To construct a lock costing, with its approaches, several millions of dollars for a draught of only 18 feet is, in the opinion of the author, unwise for reasons, some of which have already been given and for others which will appear as this discussion goes forward.

OTTAWA SHIP CANAL BETWEEN GEORGIAN BAY AND MONTREAL.

In 1858 a report was made on this project by Mr. Walter Shanley civil engineer to the Legislative Assembly of Canada.

The route lay from Lake Huron up the French River to Lake Nippissingue, thence across the watershed of the St. Lawrence and Ottawa into Trout Lake at the head of the River Matawan, a tributary of the Ottawa River, thence down the Matawan to the Ottawa River, and along its course to its mouth, thence by the Lachine canal to Montreal. The supply for the summit level was to be taken from Lake Nippissingue, which was to be raised by dams to the height of Trout Lake, 23 feet higher than its natural level, enlarging the area of

the lake from 12 to upwards of 300 square miles. At the rapids along this route dams were to be built and locks placed to overcome the difference of level. The French River, and the tributaries of the Ottawa, and the Ottawa River, also, were to be made navigable by these dams and locks. The summit would require a canal 5 miles in length with a maximum cut of 30 feet through granite rock. The summit level was to be 83 feet above Lake Huron. The lockage from the summit level down to Montreal was 615 feet, a total of 698 feet. The total distance from Georgian Bay to Montreal is 430 miles.

An examination of the manuscript copy of this report, which was kindly furnished the author by the Minister of Public Works, shows that, while Mr. Shanley was not able to obtain all of the detailed physical data which he desired, yet his general conclusions can be relied upon as reasonable. The size of the locks of Mr. Shanley's project was as follows: length 250 feet, width 50 feet, and depth on miter sills 10 feet. His estimate for the entire work was $24,000,000. While his plan contemplated throughout dams across the streams, wherever necessary to overcome rapids, his general principle was to build canals rather than to resort to high and expensive dams across the rivers.

In 1860 a second report on this project was made by Mr. T. C. Clarke to the Commissioner of Public Works. Mr. Clarke's estimate was about one-half that of Mr. Shanley, being $12,057,680. His plan, however, was much different from Mr. Shanley's, resorting still more to making as long reaches of slack water navigation as was possible, thus avoiding to a great extent the excavation through very hard and refractory rock which would be required by Mr. Shanley's project. On the other hand, Mr. Shanly preferred to cut canals at the sides of rapids rather than to raise the levels of large rivers like the Ottawa by artificial structures. There was also a large difference in the price of rock excavation, Mr. Clarke estimating it generally at an average of about $2.00 and Mr. Shanley at $4.00 per cubic yard. Mr. Shanley also estimated the cost for enlarging the Lachine Canal, 8½ miles in length near Montreal, which Mr. Clarke did not; but on the other hand Mr. Clarke estimated for a canal with 12 feet on the miter sills. Mr. Shanley estimated that the difference in cost between a 10 foot and a 12 foot canal must not be less than $5,000,000, making his estimate for a 12 foot canal $29,000,000. It is difficult to explain the difference in the estimates. It is unnecessary to go into the details of the plans and estimates of these two projects, except so far as it is necessary to use the very complete details given in Mr. Clarke's report for making an estimate for such an enlarged water-way as this paper contemplates.

For the purposes of comparison, it should be stated that Mr. Clarke's plan contemplated locks 250 feet long, 45 feet wide, and 12 feet depth on the miter sills, with a depth of 13 feet in the canals, widths in bottom of short sections 100 feet, and in long sections 146 feet, where it was intended for boats to pass, with a depth of 15 feet in the slack water reaches. A plan for the enlarged water-way proposed by the author is as follows: Locks 600 feet long, 85 feet wide, and 20 feet deep on the miter sills. The depth of canal prism 22 feet, with a width of 150 feet in short sections and 200 feet in the long sections, and with 24 feet depth in the rivers and in slack water reaches. The general methods of Mr. Shanley and Mr. Clarke to be adopted alternatively according to the conditions existing at special points. Employing the data given in Mr. Clarke's report, which appears to be accurate and quite complete, but using prices for rock excavation about midway between his and those of Mr. Shanley, and allowing for the many new obstacles which the enlarged water-way would meet in the deepening of rivers and of locks where submarine rock excavation would be required, in either of the earlier plans, the total cost of the work would be about $83,000,000, allowing for the enlargement of the Lachine Canal to the dimensions of the enlarged water-way. A careful examination leads to the inevitable conclusion, that a free unrestricted water-way cannot be found on the line of the Ottawa route at any cost which the traffic would bear. A ship railway, as an alternative, has been suggested. The course of the river is too tortuous and the cost of removing natural obstructions too great to give this alternative project serious consideration.

GEORGIAN BAY AND TORONTO SHIP CANAL, OR ITS ALTERNATIVE, THE HURONTARIO SHIP RAILWAY.

A project for a ship canal was initiated on this route as early as 1846, and an examination made by Mr. Kivas Tully, civil engineer, of Toronto. In 1851 and in 1855 further examinations were made under the auspices of the Board of Trade of Toronto, to be used at a convention of delegates from various Western cities. The Hurontario route at that convention was favourably considered, and Mr. Tully was appointed to complete the survey. There was associated with him as consulting engineer Colonel R. B. Mason of Chicago, who, himself, examined the route in 1855. The survey was completed in 1858 and published with maps and profiles. The estimate was

$22,170,150. The length of the route, which was by way of Lake Simcoe, was 100 miles, with 50 locks 265 feet in length, 55 feet in width, 12 feet lift, with 12 feet on the miter sills. Almost insuperable difficulties in the way of excavation were found at the summit, where for 10 miles there was a continuous cutting, the greatest depth of which was 197 feet and the average cutting 90 feet. A company was, however, incorporated in 1856 for carrying out the project. Its charter was amended in 1865 under the name of the Huron and Ontario Ship Canal Company.

In 1881, when the late Mr. James B. Eads was engaged in the project of a ship railway across the American Isthmus in Mexico, he was requested by Mr. Tully, the Hon. D. Blain of Toronto, and others associated with them, to give an opinion as to the feasibility of building a ship railway between Georgian Bay and Lake Ontario. His opinion was that it was not only entirely practicable, but that the route furnished one of the most favourable locations for such a construction, as the alignment was good and the grades low. This opinion was given in 1885 after three or four years of consideration at various times by Mr. Eads.

The length of the route is 66 miles. There were to be three railway tracks of the standard gauge, 4 feet 8½ inches, with rails 110 pounds per lineal yard. It was intended to transport vessels of 1000 tons register, or say 2000 tons displacement weight and 14 feet draught. The estimated cost was $12,000,000.

The author was at that time associated with Mr. Eads and familiar with the data and the discussions of the subject. In order to present it now in connection with other projects for an enlarged water-way, he has considered it important to re-examine the subject, and to have a personal examination of the country made by one of his associates, in order to supplement data already in existence, and to reform the estimates on the basis of a ship railway of larger capacity than was contemplated by Mr. Eads; that is, for vessels of a displacement weight of 5000 tons, with a draught of 20 feet, and the railway to be capable of transporting, during the navigation season, 8,000,000 tons of traffic.

It is impracticable, except at great cost, to build the railway on a straight line between the two terminal points. There will necessarily be in the central part of the route two, and perhaps three, deflection tables for changing the direction. The grades, as ascertained from all available data, will be 33 feet per mile as a maximum, although on the larger part of the route the grades will be 11 feet and 14 feet per

mile. The summit to be surmounted is 670 feet above the mean level of Lake Ontario.

The streets, public roads and railroads to be crossed can all be easily provided for. The material to be moved is entirely earth, no rock being found on the route. The harbour improvements at the termini will not be expensive. The cost of the railway fully equipped for the kind and extent of the traffic contemplated is $15, 459,318.09.

At the proper time the author will make a comparison between this route and the Ottawa route, as to distance, constructive features and other navigation features. In reference to the physical features of the two routes the advantages are altogether in favour of the ship railway. The material to be removed on the Ottawa route is almost entirely rock and of granitic quality, being syenite and gneiss, these rocks, according to Mr. Shanley's report, "thrusting themselves forward harsh, naked and repellant over the whole of the more distant portions of the line"...." On the nearer sections from the Chats Rapids to St. Ann, the formation to be dealt with, though of less impracticable character than that named above, is still rock—rock everywhere." The rock on the western part of the line is Laurentian, the very hardest that can be found. Insurmountable obstacles exist, such as the flooding of the country around Lake Nippissingue. At the time Mr. Shanley and Mr. Clarke made their reports this was an almost uninhabited country. Since then along the northern part of the lake, which would be the shore to be submerged, there is now the main line of the Canadian Pacific Railroad, and there are several towns and settlements and an improved country over nearly the entire area. It is questionable whether the plan proposed in 1860 could be carried out in 1890. Again, the fluctuation of 12 feet in the level of the Ottawa River (being 24 feet at the city of Ottawa) is a serious objection to canalizing this route. Again, the examinations show that to obtain a depth such as is proposed by the present enlarged water-way submarine excavations in hard rock must be made at various points in rivers and lakes not necessary for the depths proposed in 1860.

Another disadvantage of the Ottawa route is the difference between it and the Hurontario route in the opening and closing of the navigation seasons, a different latitude making the navigation season nearly a month shorter than by the Toronto route.

Another important difference is the difference in time of construction. The Hurontario Ship Railway could be built within three years, and no doubt, if the Government of Canada would make the necessary

appropriations, the St. Lawrence canals between Lake Ontario and Montreal could be enlarged within five years, while it would probably require 10 years time to build an enlarged water-way along the Ottawa route, and it is not improbable that 15 years would be required for this work.

As propositions for ship railways at other points will be brought forward in this paper, the author reserves the general discussion of the question of feasibility of ship railways and of their physical and commercial advantages for a subsequent point in the discussion.

WELLAND CANAL.

The present size of this canal has been given in a previous part of this paper. It is now proposed to enlarge it according to the standard dimensions of an enlarged water-way already given in connection with the plans of the Ottawa navigation. It has cost to enlarge the Welland Canal, from about 10 to 14 feet, $16,000,000. The estimate for deepening it to 20 feet and greatly enlarging the locks is $25,000,000, which is a low estimate considering the previous cost of enlarging this work.

NIAGARA FALLS SHIP CANAL.

The United States Government has taken more or less interest in this project since 1867, Congress having at that time by joint resolution instructed the Secretary of War to have an examination made. This work was performed by Col. C. E Blunt of the United States Corps of Engineers. His project was for a canal of 14 feet depth with lock chambers of 275 by 46 feet. He examined six routes, some of which present great difficulty in the ascent of what is called the Niagara Terrace. In 1888 Congress appropriated funds for an examination for a water-way around Niagara Falls, its capacity to be sufficient to float ships drawing 20 feet of water. The surveys of Col. Blunt were used for the purpose of ascertaining the feasibility and cost of building such a canal as Congress proposed. The dimensions considered were: width of canal at bottom 100 feet, depth 20½ feet, length of lock chamber 400 feet, width 80 feet, depth over miter sill 21 feet and the lift in general to be 18 feet. The route is 25 miles long, number of locks 18, estimated cost $23,617,900. A revision of this estimate on the basis of larger locks and larger canal prism, and of an increase in price of rock excavation, which the author considers advisable, makes the total cost $35,000,000.

NIAGARA FALLS SHIP RAILWAY.

The estimate is made on the Twelve Mile Creek route of Col. Blunt's surveys, beginning east of Cayuga Island, Niagara River, and ending at the mouth of Twelve Mile Creek. The length of the line is $18\frac{1}{2}$ miles. The maximum grade surmounting the Niagara Terrace is 50 feet per mile, a continuous grade of $4\frac{3}{4}$ miles. The total estimate on the same basis as the Hurontario Ship Railway, namely, for vessels of 5000 tons displacement weight, 20 feet draught, and an annual traffic of 8,000,000 tons, is $10,731,613.71, fully equipped.

MICHIGAN PENINSULA SHIP CANAL AND RAILWAY.

It is proposed to build a ship canal of the standard dimensions above given across the Michigan Peninsula, from Benton Harbour on Lake Michigan to near Monroe on Lake Erie, a distance of about 160 miles. It would require 65 locks and the crossing of 19 railroads. The estimate is $138,405,432.

A ship railway across this peninsula fully equipped will cost not over $39,000,000, and the grades will not be heavy. The height to be surmounted at the summit is 475 feet.

LAKE CHAMPLAIN ROUTE BY WAY OF THE CAUGHNAWAGA RIVER.

The estimates made at various times for a canal with locks 270 feet by 45 feet by 12 feet, from the St. Lawrence River about 8 miles above Montreal to Albany on the Hudson River, is about $20,000,000. To build this on the plan of the enlarged water-way now designed, and to deepen the Hudson from Albany to Hudson City, and to deepen Lake Champlain over long reaches, where there is now sufficient depth of water for a 12 foot navigation, but not for 20 feet, would cost at least $50,000,000, and for the purposes of an unrestricted adequate water-way for deep draught vessels from the Great Lakes to the seaboard, is apparently impracticable.

ERIE CANAL AND OSWEGO CANAL ENLARGEMENTS.

To build such a water-way as is now proposed between Buffalo and Albany would cost probably $250,000,000, and we would then have nothing but a continuous canal where the speed of vessels would be

restricted. The Oswego Canal enlargement can be dismissed also with the opinion, that to enlarge it for deep draught vessels is impracticable. It has been suggested to build a ship railway instead on one or the other of these two routes. The author considers this impracticable, not only on account of its expense, but on account of the natural and artificial obstacles that at points would prevent its construction. The Mohawk Valley is entirely occupied by two railroads (six railroad tracks), the Erie Canal, the Mohawk River and an almost continuous line of cities and towns for long distances, these natural and artificial conditions being hemmed in on either side by steep and rugged bluffs of hard rock.

ST. LAWRENCE RIVER ENLARGEMENTS.

There remains the consideration, briefly, of the enlargement of the St. Lawrence River and its canals, to give an outlet to the seaboard for either the Hurontario Ship Railway or the ship canals or ship railways at Niagara Falls and across the Michigan Peninsula. The very voluminous records of the Canadian Government extending over many years, the reports of the Chief Engineer of Canals, numerous other descriptive and statistical documents, and the examinations, maps, charts and profiles kindly furnished by the Department of Public Works of Canada have enabled the author to make an estimate for the enlargement of the canals and the deepening of the channels in the river itself between Montreal and Kingston. This estimate is based on the standard dimensions for an enlarged waterway used in making estimates of other routes. The total cost, assuming that the present canals have already been deepened to 14 feet (this work is now being done by the Canadian Government), is $27,000,000.

COMPARISON OF COMMERCIAL CONDITION.

A statement of the commercial conditions of the proposed routes is necessary in order to make a comparison between them. These conditions have an important bearing on the general question of location and advantages, and are, therefore, stated in full in the body of this paper. "The sailing distances" are steamer distances, and are compiled from many records, a selection being made from the most reliable. The time per hour forming a basis of the total time on each route is open to amendment, being in some respects a matter of opinion, but formed from much study of the subject and from definite records of speed under practical and similar conditions.

The cost of transit is made up from the actual average cost on lines now operated on rail, lake, ocean, barge and ship canals. As to the speed, time and cost on a ship railway, while there is no actual transportation of this kind in existence, yet, the results of ten years of careful study of the subject on the two principal ship railway projects of the world—the Tehuantepec and Chignecto—are used in this statement. Though made from different conditions and by persons working independently, the results closely agree and may be considered the concensus of the best thought on the subject. The figures, however, await the actual test of practice soon to be applied at the Chignecto Isthmus.

TABLE OF SAILING DISTANCES, SPEED, TIME AND COST.

Table of Sailing Distances.

	Statute Miles.
New York to Liverpool	3440
Boston to "	3211
Philadelphia to "	3625
Baltimore to "	3891
Quebec to "	3065
Quebec to Straits of Belle Isle	826
Straits of Belle Isle to Liverpool	2239
Montreal to Quebec	160
Montreal to Liverpool	3225

ALL RAIL DISTANCES.

The all-rail distance from Chicago to New York is 913 miles via the Pennsylvania Lines, 932 miles via Nickle Plate & Lackawanna Railways, and 949 miles via Nickle Plate and West Shore Railway. The all-rail distance from Chicago to Montreal is 837 miles via Grand Trunk Railway and 859 miles via Wabash and Canadian Pacific Railways.

SAILING DISTANCES FROM CHICAGO TO MONTREAL.

1st. *Via Hurontario Ship Railway and the St. Lawrence River.*

Chicago to Northern terminus of Ship Ry			570 miles
Ship Ry. (2 lifts and three deflection and turning tables).			66 "
Toronto to Montreal	Canal and 26 locks.	43.63 miles	
	Lake Ontario	161.37 "	
	St. Lawrence River	160.00 "	365 "
Chicago to Montreal			1001 miles

2nd. *Via Ottawa Navigation.*

Chicago to mouth of French River			548.00 miles.
Ottawa River & Canal	Canal	29.32 miles	
	Lakes and river ½ each	401.44 "	430.76 "
	64 Locks		
Chicago to Montreal			978.76 miles.

3rd. *Via Lakes, Welland Canal and St. Lawrence River.*

Chicago to St. Clair River			568.00 miles.
St. Clair River			41.00 "
Lake St. Clair			16.00 "
Detroit River			27.00 "
Lake Erie			218.25 "
Welland Canal (27 Locks)			26.75 "
Lake Ontario			161.00 "
St. Lawrence River	Canals	43.63	
	River	161.37	205.00 "
Chicago to Montreal			1263.00 miles.

4th. *Via Michigan Peninsula Ship Railway, Lakes, Welland Canal.*

Lake Michigan			61.00 miles.
Michigan Peninsula Ship Ry			158.50 "
Lake Erie (to Pt. Colburn)			230.00 "
Welland Canal			26.75 "
Lake Ontario (to Kingston)			161.00 "
St. Lawrence River	Canals	43.63 miles.	
	River (proper)	161.37 "	205.00 "
Chicago to Montreal			842.25 miles.

5th. *Via Michigan Peninsula Ship Ry., Lakes, Niagara Falls Ship Railway and St Lawrence River.*

Lake Michigan			61.00 miles.
Michigan Peninsula Ship Ry			158.50 "
Lake Erie (to terminus of Niagara Ship Ry.)			252.00 "
Niagara Falls Ship Railway			18.50 "
Lake Ontario			146.00 "
St. Lawrence River	Canals	43.63 miles.	
	River (proper)	161.37 "	205.00 "
			841.00 miles.

6th. *Via Michigan Peninsula Ship Ry., Lakes, Niagara Falls Ship Canal and St. Lawrence River.*

Lake Michigan			61.00 miles
Michigan Peninsula Ship Railway			158.50 "
Lake Erie (to terminus of Niagara Ship Canal)			252.00 "
Niagara Falls Ship Canal			25.00 "
Lake Ontario			139.50 "
St. Lawrence River	Canals	43.63 miles.	
	River (proper)	161.37 "	205.00 "
Chicago to Montreal			841.00 miles.

DISTANCE BY DIFFERENT ROUTES.

1st.	Hurontario Ship Railway	1001.00 miles
2nd.	Ottawa Navigation	978.76 "
3rd.	Lakes, Welland Canal & St. Lawrence River	1263.00 "
4th.	Michigan Peninsula Ship Ry. & Welland Canal	842.25 "
5th.	Michigan Peninsula Ship Ry., Niagara Falls Ship Ry., etc	841.00 "
6th.	Michigan Peninsula Ship Ry., Niagara Falls Ship Canal	841.00 "

RATES OF SPEED (STEAMERS).

Rate of speed on the Ocean and Lakes, 15 miles per hour.
" " Ship railways and Rivers, 10 miles per hour.
" from Montreal to Quebec, 10 miles per hour.
" on the Canals, 7 miles per hour.
" " Welland and Niagara falls Canals, 4 miles per hour.

Lockage and Ship Railway lifts and deflection tables, 30 minutes each.

SCHEDULE OF DISTANCES AND SAILING (STEAMING) TIME FROM CHICAGO TO MONTREAL.

1st. *Lakes, Hurontario Ship Railway and St. Lawrence River.*

				hours.
By Lakes (570 and 160) =	730 miles	at 15	miles per hour =	48.67
By River	161.37 "	10	" "	16.14
By Ship Railway	66.00 "	10	" "	6.60
By Canals	43.63 "	7	" "	6.23
By detentions on Ship Ry				2.50
" in locks (26 at 30 minutes)				13.00
Sailing time Chicago to Montreal				93.14

2nd. *Ottawa Navigation.*

By Lake	548.00 miles at	15	miles per hour......	36.53	hours.
By small lakes	200.72 "	15	"	13.38	"
By Rivers	200.72 "	10	"	20.07	"
By Canals	29.32 "	7	"	4.19	"
By detentions in 64 locks..................				32.00	"
Sailing time Chicago to Montreal..........................				106.17	hours.

3rd. *Lakes, Welland Canal and St. Lawrence River.*

				hours.
By Lake—Chicago to St. Clair River	568 mi. at	15	mi. per hr.	37.87
By St. Clair River and Canal	41.00 "	10	"	4.10
By Lake St. Clair	16.00 "	15	"	1.07
By Detroit River	27.00 "	10	"	2.70
By Lake Erie	218.25 "	15	"	14.55
By Welland Canal	26.75 "	4	"	6.69
By Lake Ontario	161.00 "	15	"	10.73
St. Lawrence River	161.37 "	10	"	16.14
" " Canals	43.63 "	7	"	6.25
By detention in Welland Canal—27 locks—at ½ hour each......				13.50
" " in St. Lawrence Canals—26 locks at ½ each.......				13.00
Sailing time Chicago to Montreal..................................				126.58

4th. *Via Michigan Ship Railway, Lakes, Welland Canal, etc.*

By Lake Michigan	61 mi. at	15	mi. per hr.	4.07	hrs.
By Mich. Peninsula Ship Ry.	158½ "	10	"	15.85	"
By Lake Erie (to Pt. Colburn)	230.00 "	15	"	15.33	"
By Welland Canal	26.75 "	4	"	6.69	"
By Lake Ontario	161.00 "	15	"	10.73	"
By St. Lawrence River	161.37 "	10	"	16.14	"
" " Canals	43.63 "	7	"	6.23	"
By detentions on Ship Ry..................				550	hrs.
" " in Welland Canal..................................				13.50	"
" " in St. Lawrence Canals......				13.00	"
Sailing time Chicago to Montreal..........................				107.04	hrs.

5th. *Via Mich. Peninsula Ship Ry., Lakes, Niagara Falls Ship Railway and St. Lawrence River.*

By Lake Michigan	61	mi. at	15	mi.	per hour	4.07	hours.
By Mich. Pen. Ship. Ry.	158½	"	10	"	" "	15.85	"
By Lake Erie	252.00	"	15	"	" "	16.80	"
By Niagara Falls Ship Ry.	18½	"	10	"	" "	1.85	"
By Lake Ontario	146.00	"	15	"	" "	9.73	"
By St. Lawrence River	161.37	"	10	"	" "	16.14	"
By St. Lawrence Canals	43.63	"	7	"	" "	6.23	"
By detention on Mich. Pen. Ship Ry.						5.50	"
" Niagara Falls Ship Ry.						1.50	"
" in St. Lawrence Canals						13.00	"
Sailing time Chicago to Montreal						90.67	hours.

6th. *Via Michigan Peninsula Ship Railway, Lakes, Niagara Falls Ship Canal and St. Lawrence River.*

By Lake Michigan	61	miles at	15	mi.	per	hour 4.07	hrs.
" Mich. Pen. Ship Ry.	158½	"	10	"	"	" 15.85	"
" Lake Erie	252	"	15	"	"	" 16.80	"
" Niagara Falls Ship Canal	25	"	10	"	"	" 2.50	"
" Lake Ontario	139¼	"	15	"	"	" 9.30	"
" St. Lawrence River	161.37	"	10	"	"	" 16.14	"
" St. Lawrence Canals	43.63	"	7	"	"	" 6.23	"
By detention on Mich. Peninsula Ship Ry.						5.50	"
" " " Niagara Falls Canal						9.00	"
" " " St. Lawrence Canals						13.00	"
Sailing time Chicago to Montreal						98.39	"

RECAPITULATION.

	hours
1st. Via Lakes, Hurontario Ship Ry. and St. Lawrence River	93.14
2nd. Via Ottawa Navigation	106.17
3rd. Via Lakes, Welland Canal and St. Lawrence River	126.58
4th. Michigan Peninsula Ship Ry. Lakes, Welland and Niagara Falls Canal, etc.	107.04
5th. Michigan Ship Ry. Lakes & Niagara Falls Ship Ry.	90.67
6th. " Ship Ry. Lakes, Niagara Falls Ship Canal, etc.	98.39

It is necessary to give the following notes for the purpose of ascertaining the correct basis of the cost per ton per mile. On this basis the tables which follow have been prepared :—

ACTUAL RAIL RATES, SEASONS OF 1889 AND 1890.

The lowest summer rate from Chicago to New York was 20 cents per 100 pounds on grain, flour, etc., or $4.00 per ton, $4\frac{4}{10}$ mills per ton per mile via shortest line.

About $\frac{9}{10}$ of the freight East and West comes under classes 4, 5 and 6.

At 25 cents per 100 pounds Chicago to New York (the regular schedule rate), or $5.00 per ton, the rate per ton per mile is $5\frac{47}{100}$ mills. The mean of these two rates is almost exactly one half cent. per ton per mile.

The summer rate from Buffalo to New York is 11 cents per 100 pounds, or $2.20 per ton = $5\frac{38}{100}$ mills per ton per mile.

The regular rate on grain from Buffalo to New York is 13 cents per 100 pounds, or $2.60 per ton = $6\frac{36}{100}$ mills per ton per mile.

CHICAGO TO BOSTON.

The summer rate on grain is 25 cents per 100 pounds, or $5.00 per ton = 5 mills per ton per mile. The winter and all year rate is 30 cents per 100 pounds = $6.00 per ton, or 6 mills per ton per mile.

The average rates from Chicago to Montreal are the same as from Chicago to New York, which would make a higher rate per ton per mile than is given above from Chicago to New York.

Taking rates per ton per mile from Chicago to New York and applying on roads from Chicago to Montreal will give the following :—

Chicago to Montreal, summer rate..................	$3.68 per ton.
Regular rate...	$4.58 " "

Taking same rates from Chicago to Montreal as rule to New York, we have :—

Chicago to Montreal, summer rate, about $4\frac{3}{4}$ mills per ton per mile ($4\frac{78}{100}$ mills), and regular rate equals almost 6 mills per ton per mile.

It is safe to assume that the rates from Chicago to Montreal on export freight will never be much, if any, lower than those to New York.

Inasmuch as the ocean voyage from Montreal to Liverpool is only 190 miles shorter than from New York, the difference in rates could not be more than 10 cents per ton.

From the above it is safe to assume $\frac{1}{2}$ cent per ton per mile for the railroad rate over all lines. Assuming this as the rail rate, and the following rates over different portions of the water route and over

ship railways, we have the table given below. In order to fairly compare routes, the rate per ton per mile covers cost of operation of ship railways and canals and six per cent. interest on cost of construction.

TABLE.

RATE OVER HURONTARIO SHIP RY.—$3\frac{4}{10}$ MILLS PER TON MILE.

Rate over Niagara Falls Ship Ry............	7 mills per ton mile.
" on Lakes..................	1½ " " " "
" " Ocean..................................	½ " " " "
" " Michigan Peninsula Ship Ry.....	3½ " " " "
" " " " " Canal...	8 " " " "
" " Ottawa Route.........................	5 " " " "
" " St. Lawrence Canals................	7 " " " "
" " Niagara Falls Ship Canal.........	12.5 " " " "
" " Welland Canal	10 " " " "

One of the conditions importantly affecting the various routes to the seaboard under consideration is the time lost during the year by the rigor of a Northern climate. The effect which this suspension of navigation, of from 126 to 150 days out of the 365, will have upon the transportation question it is difficult to estimate.

A careful examination has been made of the length of time each year that different harbours will be closed by ice. The table prepared by Mr. L. E. Cooley, late chief engineer of the Chicago Drainage District, appears to be the most reliable, although authorities differ, and it is used to determine the length of time that each of the routes will probably be open for business.

LOCALITY.	No. years Observation.	No. days closed average.	Date closing.	Date opening.	Remarks.
Erie Canal	20	153	Dec. 3	May 5	Official closing
Welland Canal	20	136	" 9	Apr. 24	Actual closing
Buffalo, N. Y.	10	126		" 16	Say 126 days
Detroit River	7	121	" 2	" 2	
Straits of Mackinaw	20	140		" 20	" 140 days
St. Mary's Canal	10	147	" 3	" 29	Actual closing
Duluth	9	132	" 26	May 7	
Montreal	10	131	" 15	Apr. 24	
Hudson River	19	107	" 12	Mch. 29	Albany, N. Y.
Ill. & Mich. Canal	41	126	Nov. 26	Apr. 1	Official closing
Illinois River	11 & 34	70	Dec. 25	Mch. 4	Morris, Ill.
Mississippi River	25	30½	" 23	Jan. 23	St. Louis, Mo.

Using the above mentioned table, and 30 days for one month, we find the various routes will be opened for business, as follows:—

DESCRIPTION OF ROUTE.

No. of Routes.	Days open.	
1. Hurontario Route	225	days.
2. Ottawa Navigation	205	"
3. Lakes, Welland Canal & St. Lawrence River	225	"
4. Peninsular Routes, Lakes, Welland Canal, etc...	229	"
5. Peninsular Route, Lakes, Niagara Falls Ship Ry. and St. Lawrence River	234	"
6. Peninsular Route, Lakes, Niagara Falls Ship Canal and St. Lawrence River	229	"

The following table gives the results of all of the preceding tables, relating to length of route, time of transit, cost per ton, and length of time that each route will be open.

CHICAGO TO LIVERPOOL.

Description of route.

No. of Routes:	Length miles	Time in hrs.	Cost per ton	No. of days route is open.
1. Hurontario Ship Ry., Lakes and St. Lawrence River	4226	313.47	$3.48	225
2. Lakes and Ottawa Navigation	4203.76	326.50	4.59	205
3. Lakes, Welland Canal and St. Lawrence River	4488	346.91	3.97	225
4. Mich. Peninsula Ship Ry., Lakes, Welland Canal, etc.	4067.25	327.37	3.66	229
5. Mich. Pen. Ship Ry., Lakes, Niag. Falls Ship. Ry. & St. Lawrence	4066	311.00	3.53	234
6. Mich. Pen. Ship Ry., Niag. Falls Ship Canal and St. Lawrence	4066	318.72	3.70	229
7. All rail to Montreal	4062	328.33	6.25	234
8. All rail to New York	4353	337.33	6.74	365

NOTE.—Should the Canadian Government enlarge the St. Lawrence Canals at its own expense, deepen the river where required, and

remove the tolls to commerce from Lake Ontario to Montreal, as it has done seaward of Montreal, there can be deducted from total cost of transportation from the Great Lakes to Liverpool by this route 20 to 22 cents per ton. The Hurontario route to Liverpool will then compare with the all-rail route via New York as $3.26 per ton is to $6.74, that is, less than one-half the cost by rail, or a saving to commerce in one year on 8,000,000 tons of traffic, of more than the entire estimated cost of preparing the enlarged water-way from the foot of Lake Ontario to the sea.

The competition in English and other importing markets of Europe between the wheat of our Northwest, the Pacific Coast, India, Russia and the Argentine is so close, that a substantial advantage in cost of transportation like the above to both Canadian and United States cereal producers will at once work a revolution in trade, and lead to an important development of agricultural products and to a material prosperity over the 450,000 square miles, comprising the basin of the Great Lakes, and extending to the lands outside and remote from it, but capable of reaching, by rail or water routes, its seaports, as the great cities of the lake will then be.

SHIP RAILWAY DISCUSSION.

The author has, without any hesitation, placed on an equality, as transportation methods, the ship railway and the ship canal. The former he considers superior in many respects.

1st. The cost of construction at each special location is more than 50 per cent. less than the cost of a ship canal to handle the same class of vessels and an equal amount of traffic.

2nd. The cost of operation and maintenance will be less.

3rd. The rate of speed will be greater, and there will be much less detention *en route.*

These features have been brought out fully in the plans of the Tehuantepec and Chignecto Ship Railways, and in the discussions which for ten years have been before the world, comparing the methods by railroad and barge canal and by ship railway and ship canal. The most extended, minute and careful examinations and investigations have been made. The results in the case of the Tehuantepec Ship Railway were:—

1st. The Mexican Government became so well assured of the practicability of the method, that it agreed to guarantee the interest on the cost of the railway up to $1,200,000 per annum.

2nd. The leading and most experienced naval architects of this country and England gave their full approval to the method and the plan.

3rd. Many vessel owners and navigators of England and this country expressed an entire willingness to entrust their vessels to the ship railway.

As to the Chignecto Ship Railway, the Dominion Government wisely adopted the plan of the ship railway instead of the ship canal, and guaranteed the interest on the cost of the work. English capital is constructing it, and the leading engineers of Great Britain, if not of the world, have charge of its construction.

The United States Government, after an exhaustive examination in this country and Europe, by a Board composed of three Government engineers of high rank and ability, adopted a ship, or a boat, railway to avoid the rapids of the Columbia River in Oregon.

The well-considered detailed plans of the Tehuantepec Ship Railway, worked out carefully by the late Mr. James B. Eads, and which contemplated a railway for the transit of vessels of a displacement weight of 5000 tons, have formed the basis of the plans for the Hurontario, Michigan Peninsula and Niagara Falls Ship Railways proposed in this paper, and the cost of transportation, carefully ascertained by Mr. Eads and his associates, has been applied to these railways, taking into due account the difference in conditions.

The author had the good fortune last summer to examine personally the route, the constructions and the detailed plans of the substructure, superstructure and the mechanical appliances of the lifting docks, and the equipment as well, including the motive power of the Chignecto Ship Railway. There is no doubt in his mind of entire success in the construction, operation and economy of this railway

There is nothing novel in the methods, only in the combination of methods. Vessels are at present raised out of the water continually, whether loaded or unloaded, on hydraulic lifts, by marine railways and by floating docks.

The views and the advanced thought of ship builders on the Lakes may be seen from the following extract from a letter of date December 19th, 1890, by Mr. W. I. Babcock, manager of the Chicago Ship Building Company, which is now engaged in building large steel vessels at Chicago, on Lake Michigan, and to whose Company the author had written to ascertain if it was prepared to build vessels of 5000 tons displacement weight, when laden, with a draft of 20 feet, to navigate the route between Chicago and Liverpool, 66 miles of which

would be over a ship railway between Georgian Bay and Toronto Mr. Babcock, on behalf of his Company, replies as follows:—

"The question of the size of vessels that can be built here seems to be the only one on which Mr. Corthell desires information, and I would, therefore, say, that at this yard we can build anything from 400 feet over all, 50 feet beam, and any depth, provided that a channel such as he specifies can be used to salt water. There would be, of course, no reason why we could not build vessels for any service there if we get money enough for them. As for transporting such vessels on a ship railway between Georgian Bay and Toronto, I believe such a carriage is entirely feasible, and that no special arrangement would be required on the vessel herself at all. It would, therefore, be entirely immaterial to us as ship builders what was done with the vessel after she left the yard."

The increasing size of rolling stock, both motive power and freight cars, on ordinary railroads, has proven the great advantage in carrying greater and greater loads at one time. A few years ago 10 ton cars were the rule in this country. Now, 30 tons are becoming more and more numerous. Cars for still larger loads for special purposes are becoming more and more common, and the locomotives have increased in weight and power from 30 and 40 tons to 90 and 100 tons, and the cost of transportation has been reduced from 2½ cents to ½ cent per ton mile.

A ship railway is the logical result of the continual improvements in railroad methods from the time of the first railroad to the present. If it is possible to raise vessels and transport them over land with safety and economy, why should they be compelled to make great detours costing time and money?

If the immense business between the St. Lawrence and the coast of New Brunswick and New England can save 500 to 700 miles by operating a railway 17 miles long across the Chignecto Isthmus, why should it continue to take this long and dangerous voyage around Nova Scotia? If engineering skill can provide lifts and a railway and motive power that can haul vessels weighing 2000 to 2,500 tons, as already arranged for at Chignecto, who will say that it cannot design, construct and successfully operate a railway that will handle vessels weighing 5000 tons? Necessity knows no law, and this applies to commerce as well as to other things; and the demands of this commerce and of a great people, seeking the markets of the world by the least expensive route, will be satisfied with nothing less than the most approved and economical methods which it is in the power of man to provide.

The question now arises, how can the desired and best route be provided? Will the mutual interests of two great countries between which the St. Lawrence River is a dividing line, in part, and through one of which, having passed an artificial and arbitrary line, it finds its way to the sea, bearing the commerce with it, be willing to unite to construct the ship canals and ship railways necessary to remove the obstructions to navigation? Will the Great Northwest, both of the United States and Canada, with its millions of people, its rapidly growing cities, centers already of finance and commerce, with the constantly increasing business of the Great Lakes—a common heritage of both nations and free to both, and God-given—will these two nations, with so much in common, permit longer arbitrary national boundary lines to remain a barrier—a Chinese wall—to the commerce of both? Shall cities like Chicago, Milwaukee, Duluth, Buffalo, Cleveland and Toronto be longer compelled to send their exports to Europe and receive their imports by expensive channels, when they can load them for Liverpool or Havre at their own wharves, and receive their imports directly at those wharves from the ports of the Old World?

If these two Governments, so closely united in commercial relations, cannot, on account of grave political reasons, unite in the construction of the desired route, then why should not Canada herself undertake the task and assume the burden of its cost? The reasonable plan appears to be for that Government to enlarge the St. Lawrence Canals and the intermediate river reaches, where necessary, for the navigation recommended by the author, and to encourage the construction of the Hurontario Ship Railway by guaranteeing the interest on its cost, as it has already done on that of the Chignecto Ship Railway. That Government must now provide these new and enlarged channels of commerce, or see the vast amounts already expended practically lost through its inability, or its unwillingness, to meet the demands of commerce. It will inevitably see the greatest commerce of the world diverted from its natural channel, and taken out of its domains into the artificial channels of its neighbour's territory, to enrich and develop a country lying along these artificial routes. The commerce and financial importance in every way to Montreal and to other cities, both Canadian and United States, situated on this enlarged natural water-way, can scarcely be over-estimated. To be in the pathway of such a commerce, as will move from the great Northwest to the Old World and back again, will insure to any city situated upon it a prosperity—commercial, industrial and financial—surpassing the most sanguine anticipations.

The argument may be brought forward that, on account of the close

competition between the present routes by way of the several ports along the Atlantic seaboard to Liverpool, there is such slight difference in rates, that no advantage would accrue from an enlarged water-way commensurate with the great expenditures required to obtain it. Granted that the case may even be similar to that of the Mississippi River, upon which the United States Government is spending already vast amounts in removing the obstructions from its mouth nearly to its source, but which does not have upon it the amount of business anticipated—the railroads being able on shorter lines to move the freight to the seaboard—nevertheless it stands there as a great regulator and minimizer of freights. When for any reason the slightest increase in rates occurs over the rail routes, the freight is given to the barges and boats, and the products then reach New York and other Atlantic ports via the mouth of the Mississippi, and the rates again come down to a water rate.

If an enlarged water-way shall compel the slightest reduction in through rates to the Atlantic seaboard and Europe, the producers will reap the advantage, whether the new route obtains the larger part of the business or not. If this route can carry freights to Liverpool cheaper than the present rates, and shall do so to any extent whatever, then all the other routes must come down in rates to meet it.

There is, however, no question about this enlarged channel from Chicago, Duluth and Port Arthur to Liverpool obtaining a large part of the European business. The enlarged facilities proposed will vastly increase the volume of the carrying trade between the Northwest and the Old World. The advantage to the country bordering on the Great Lakes and the St. Lawrence can scarcely be over-estimated. The increase in commerce everywhere, and the material prosperity sure to quickly follow the opening of such a route outlined in this paper, is beyond conception.

It is estimated by statisticians that the Mississippi River gives a direct advantage to the producers of the Mississippi Valley, amounting to from 50,000,000 to 100,000,000 dollars per annum. The St. Lawrence route will give a direct advantage not only to agricultural producers but to manufacturers, importers and merchants, and through them to all the people. "DIRECT TRADE WITH EUROPE" should be the demand of the Northwest and of all the country tributary to it. The direct pecuniary advantage to the people should not be estimated at less than $200,000,000 per annum.

As civil engineers we should promote in all possible ways the development of these commercial routes, and lend our good offices to

the patriotic effort to improve the commercial conditions of what is after all a common country.

The author is greatly indebted to the officials of the Dominion and United States Government, and to other persons, for the information necessary to compile and to write this paper. He is particularly indebted to Sir Hector Langevin, Minister of Public Works of the Dominion of Canada; and Mr. Baillairgé, Deputy Minister; Mr. H. F. Perley, chief engineer Public Works Department; Mr. John Kennedy, chief engineer of the Montreal Harbour Commission; Mr. G. P. Brophy and Mr. Thomas C. Keefer of Ottawa, Mr. Walter Shanley of Montreal, M. P., Superintendent U. S. Census; United States Commissioner of Navigation; Chief of the Bureau of Statistics U. S.; Colonel O. M. Poe, U. S. engineer; Capt. W. L. Marshall, U. S. engineer; Hon. D. Blain, Mr. Kivas Tully and Mr. Joseph Blakeley of Toronto, also to Mr. Chas. H. Keep, secretary Lake Carriers' Association; secretaries of the Boards of Trade of Buffalo, Cleveland, Chicago and Duluth; Mr. L. E. Cooley, president Western Society of Engineers; and to the author's associate, Mr. A. F. Robinson, civil engineer.

From the drawing accompanying this Paper Plate II has been prepared.

DISCUSSION ON MR. CORTHELL'S PAPER ON "ENLARGED WATERWAY," ETC.

TORONTO BRANCH DISCUSSION.

Mr. Blain.

Mr. David Blain said he fully endorsed Mr. Corthell's views, and considered the Ottawa River and Trout Lake route as now impracticable, and that the Georgian Bay and Lake Ontario route offers greater advantages.

Prof. Galbraith

Professor Galbraith said the fact of there being at present no ship railway in operation, and hence that no practical knowledge exists of its working, must not be lost sight of. The speaker would introduce Captain Crangle, who would give his views.

Capt. Crangle.

Captain Crangle said he was a practical sailor, having had 35 years experience. That there is being now introduced a new type of vessel called the "Whaleback," the object being large tonnage capacity at minimum amount of material used in building; and he was of opinion that a vessel of this kind would suffer serious injury by being carried on a ship railway. He would not like to say a steamship railway is not feasible, but it is as yet unproven. He considered the Chignecto Ship Railway may be feasible for small coasting craft, but he had grave doubts whether a vessel 250 ft. in length could be transported by a ship railway without occasioning damage to the vessel, the weight of the vessel and cargo being 3,000 tons. He considered that the vessel should be in a cradle on a pivot, so as to keep it always level; that one of the greatest objections he sees to a ship railway is that it is similar to dry docking a loaded vessel, and in his experience he could always see places where unequal straining had occurred by such a process.

Mr. Redway.

Mr. Redway observed that the question of carrying a loaded vessel by railway had been discussed in England 10 years ago, when Captain Eads presented his projected Isthmus of Tehuantepec Ship Railway, and it was then generally admitted to be feasible. That at the Edinburgh Exhibition, held a short time ago, there was a model shown of the method of transporting a loaded vessel in water over a ship railway, and that the Commission appointed to report considered that a ship

and cargo weighing 5,000 tons could be safely carried any distance on a properly constructed ship railway.

Prof. Galbraith

Professor Galbraith said it is the carrying out of the principle on a large scale where the difficulty arises, the tank would have to be transported with the same care as the ship.

Mr. Redway.

Mr. Redway replied, it is not a tank.

Prof. Galbraith

Professor Galbraith observed it is a vessel floating in a tank, whether there is $\frac{1}{16}$ of an inch of water or 16 feet of water. The experiment on a small scale may be successful, but carried out practically the trouble increases in geometric ratio.

Mr. Tully

Mr. Kivas Tully said he felt obliged for the invitation to be present. He considered that raising loaded vessels out of water and carrying by railway had been pronounced upon as feasible by eminent experts; that personally he had no doubt it could be done; that a ship railway is not subject to a difference of grade; that no curves are less than 20 miles radius; that deflections are done by turn-tables. The platform will be rigid, the cars supported by a large number of wheels, none of which will carry more than five or six tons; that if any one doubted the feasibility of lifting a vessel out of water and carrying by a ship railway, he would refer him to the model in New York, made under the directions of the late Captain Eads.

Mr. Macdougal

Mr. Alan Macdougall considered it difficult to discuss the engineering question involved in the carriage of loaded vessels up to 5,000 tons gross by ship railway without experience, and that the operation of the Chignecto Ship Railway would be awaited with interest.

CORRESPONDENCE.

Hon. E. Murphy

The Hon. Edward Murphy of Montreal considered the undertaking too great, and that it would involve a serious loss of time to vessels in transit.

Mr. Clarke.

Mr. Thos. C. Clarke endorses Mr. Corthell's views as to the superior advantages of a ship railway over any other means for connecting Lakes Huron and Ontario.

Mr. Budden.

Mr. Henry A. Budden of Montreal considers the operation of the Chignecto Ship Railway necessary to establish the feasibility of the project aimed at by Mr Corthell. Mr. Budden considers transportation of grain by barges from Port Colborne on Lake Erie to Montreal, and thence by ocean steamer, as the best means of transit.

Mr. Tate.

Mr. R. F. Tate is satisfied that a ship canal as proposed can be constructed and successfully operated, and considers that Mr. Corthell is right in his dimensions for securing ample water-way—both breadth and depth.

Mr. Gisborne.

Mr. F. N. Gisborne considers the economic capacity for grain-carrying vessels must be considered independently of their mode of transit by canal or ship railway, and he considers the route via the Peace and Saskatchewan Rivers, via St. James Bay and St. Johns Lake to Seven Islands Harbour in the Gulf of St. Lawrence, as offering in the future an effective route to England for the North West.

Mr. Ruttan.

Mr. H. N. Ruttan of Winnipeg points out a practicable water route to Liverpool from Fargo and Winnipeg, via Lake Winnipeg, the Nelson or Hayes Rivers and Hudson Bay.

That both the Nelson and Hayes Rivers offer practical routes to the sea from Lake Winnipeg, and that by improving the Nelson River and the construction of ship canals or ship railways, ocean steamers may be brought into Lake Winnipeg, and possibly to the mouth of the Red River, offers an alternative route between Lake Winnipeg and Hudson Bay.

That the Hayes River is open from about the 20th May to the 20th November, and that Hudson Straits are navigable for at least 4½ months in the year. That the distance in miles from Winnipeg via Hudson Bay to Liverpool is 3,262.

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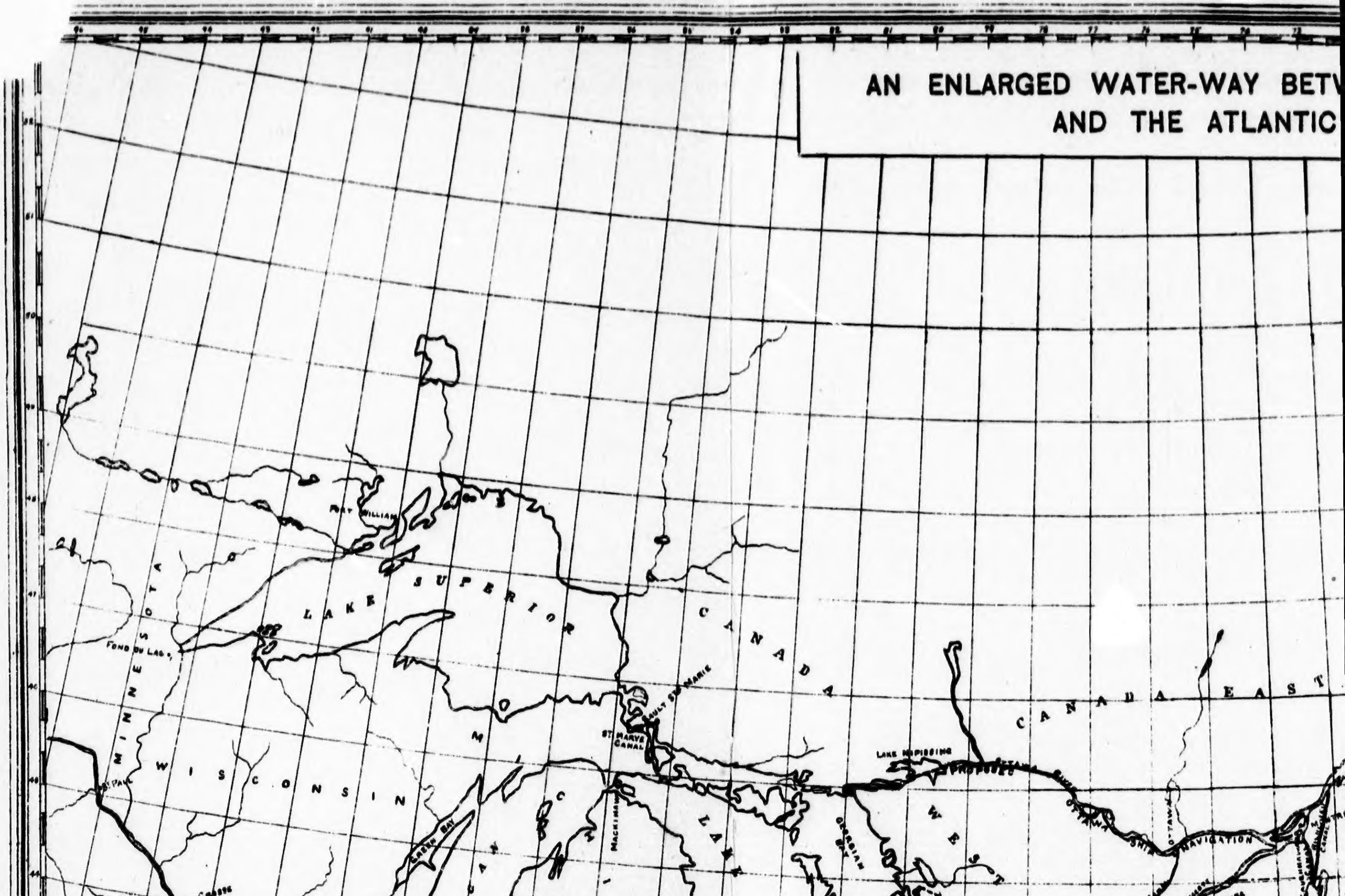
AN ENLARGED WATER-WAY BETW
AND THE ATLANTIC
LAKE SUPERIOR
CANADA
CANADA EAST
CANADA WEST
MINNESOTA
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MICHIGAN
IOWA
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INDIANA
OHIO
PENNSYLVANIA
NEW YORK
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
LAKE NIPISSING
LAKE SIMCOE
GREEN BAY
GEORGIAN BAY
FORT WILLIAM
FOND DU LAC
SAULT STE MARIE
ST MARYS CANAL
ST PAUL
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MADISON
MILWAUKEE
DUBUQUE
GALENA
DAVENPORT
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MICHIGAN PENINSULA SHIP RAILWAY
OTTAWA SHIP NAVIGATION
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